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Hain

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(54) **SUSPENSION**

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(58) **Field of Search** 415/134, 136, 415/138, 139

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,488,867 A * 11/1949 Judson 415/136
2,996,279 A * 8/1961 Lorett et al. 415/134
3,529,904 A * 9/1970 Borden et al. 415/136
3,965,066 A * 6/1976 Sterman et al. 415/138
4,441,313 A 4/1984 Joubert et al.
5,076,049 A 12/1991 Von Benken et al.
5,259,183 A 11/1993 Debeneix

FOREIGN PATENT DOCUMENTS

CH 363661 9/1962
DE 1004201 3/1957
DE 0716219 A1 6/1996
DE 19807247 C2 4/2000

* cited by examiner

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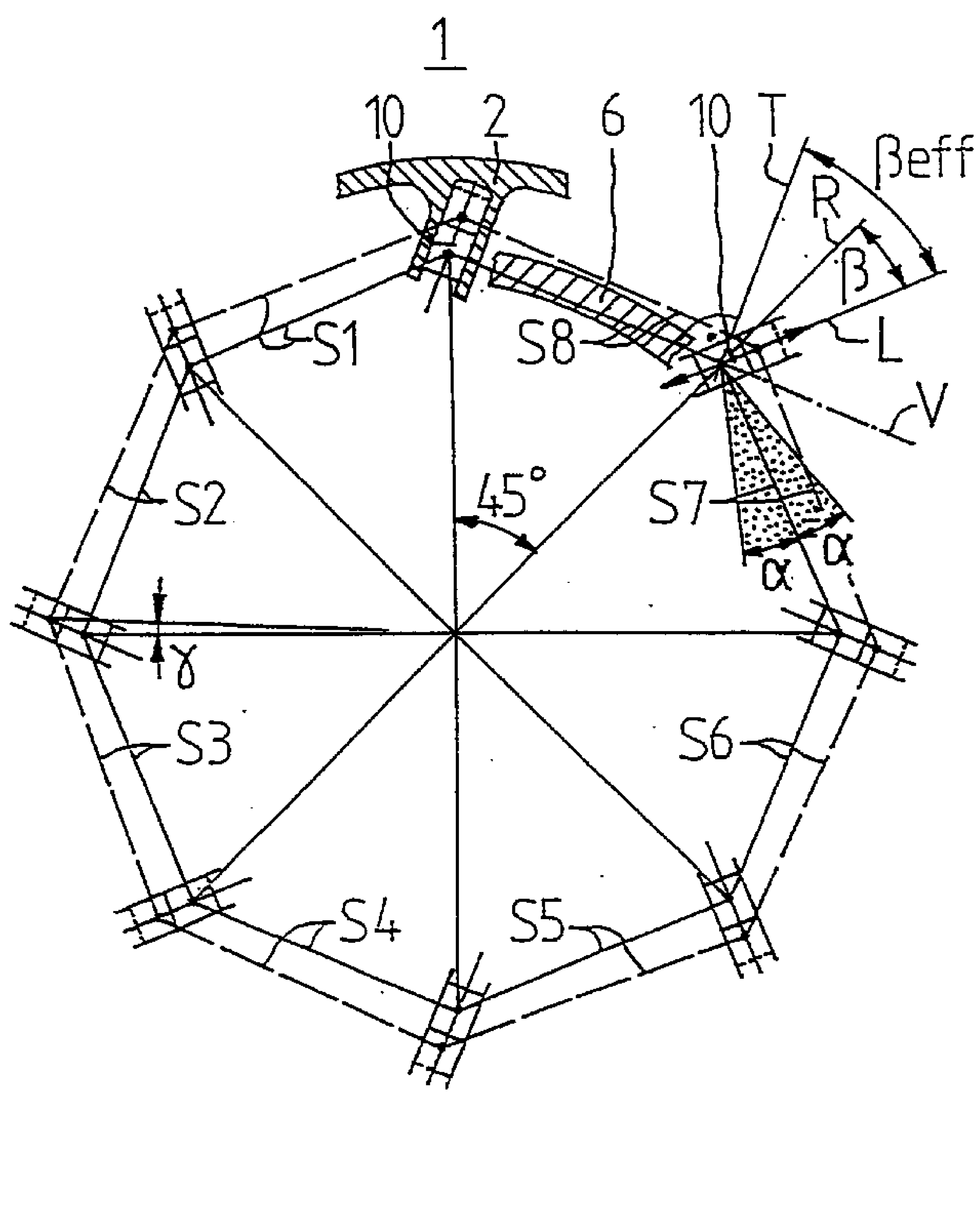
(57) **ABSTRACT**

A suspension of an annular secondary structure on a primary structure, in the form of a spoke-type centering device, has at least three sliding guides distributed uniformly over the structure circumference. Each sliding guide allows at least a linear relative movement of the structures transversely to their axial direction. The linear direction of movement of each sliding guide runs, in relation to the structure-related radial direction at the location of the sliding guide, at an angle having radial and tangential direction components.

20 Claims, 2 Drawing Sheets



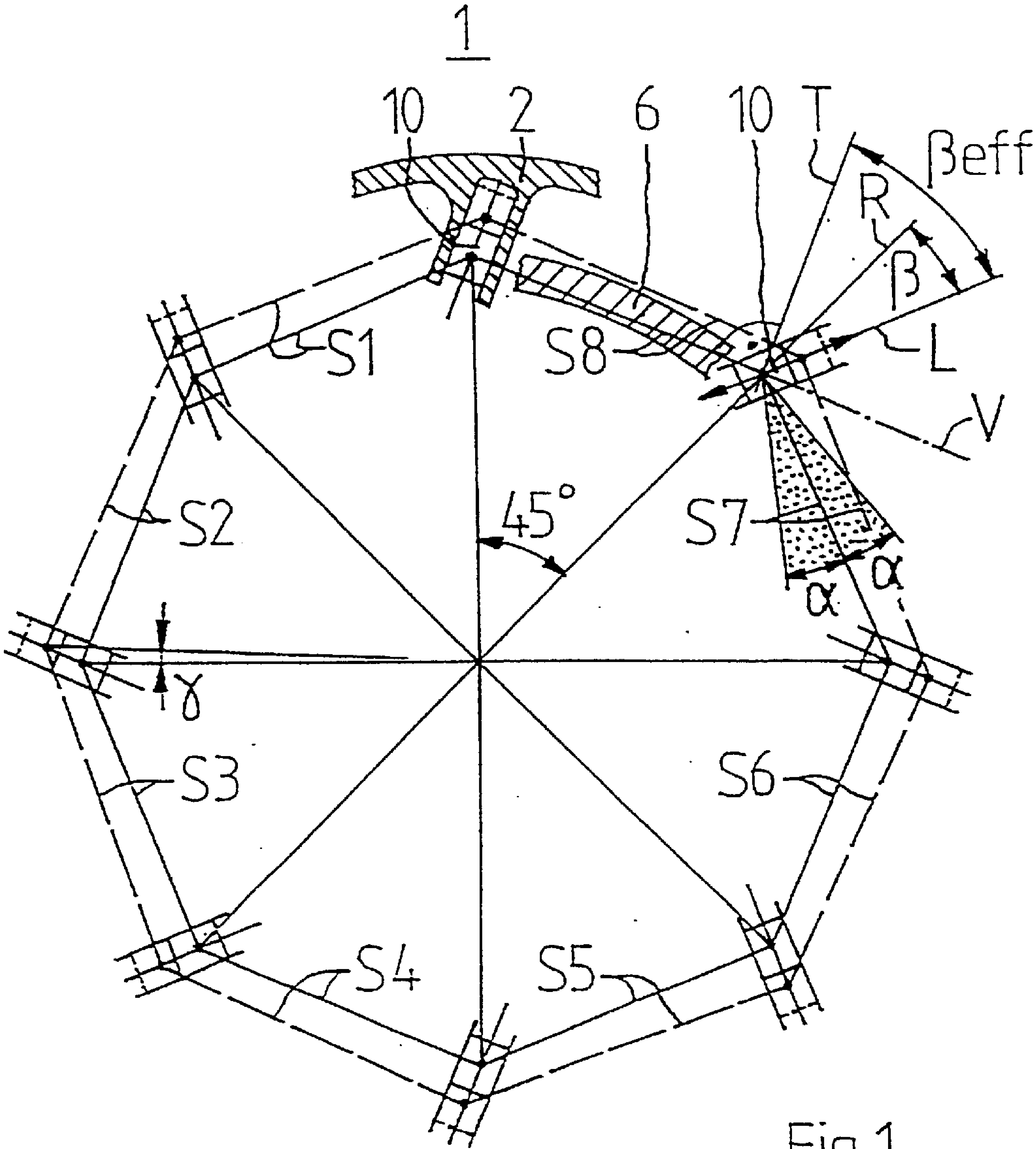


Fig.1

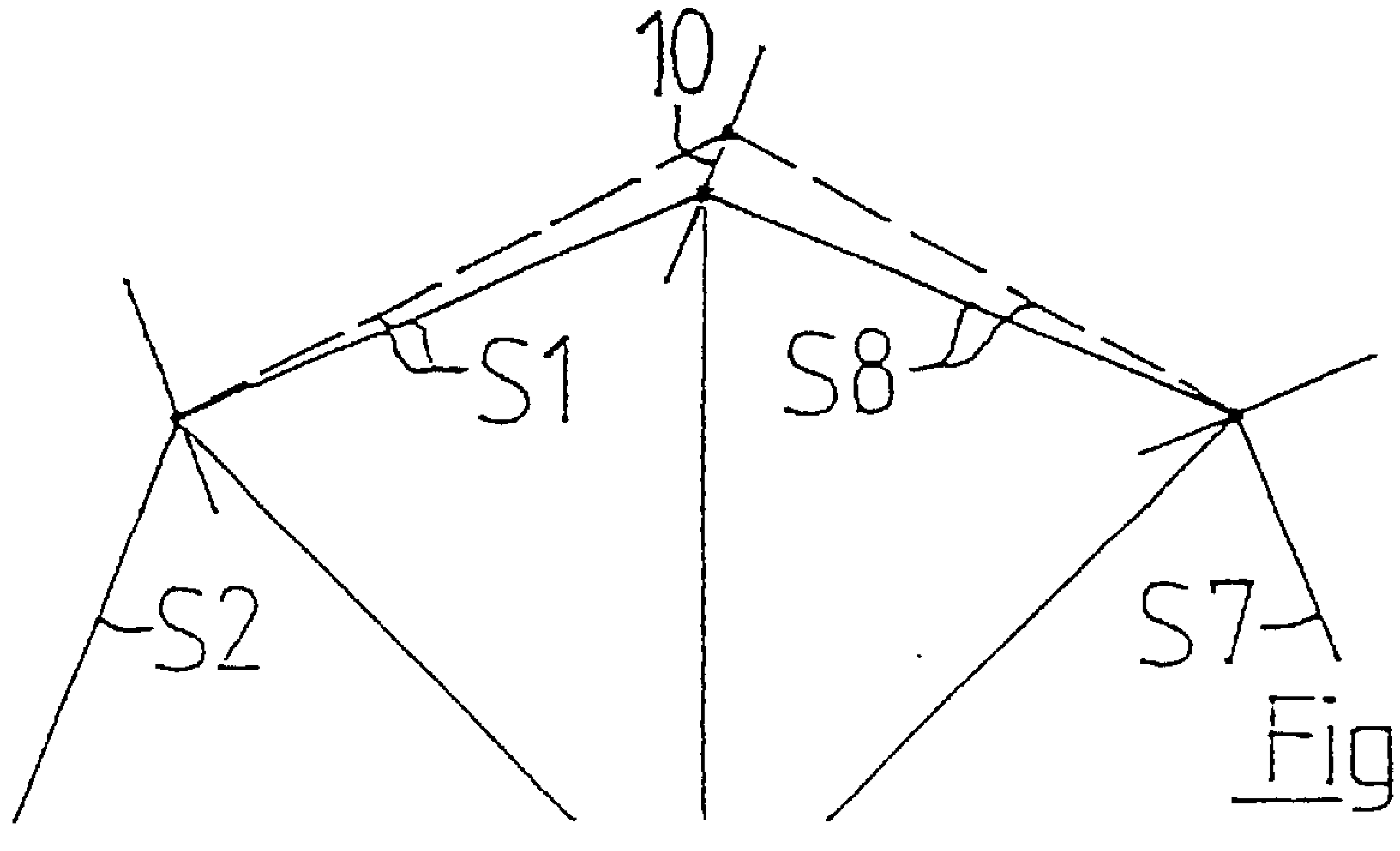


Fig.2

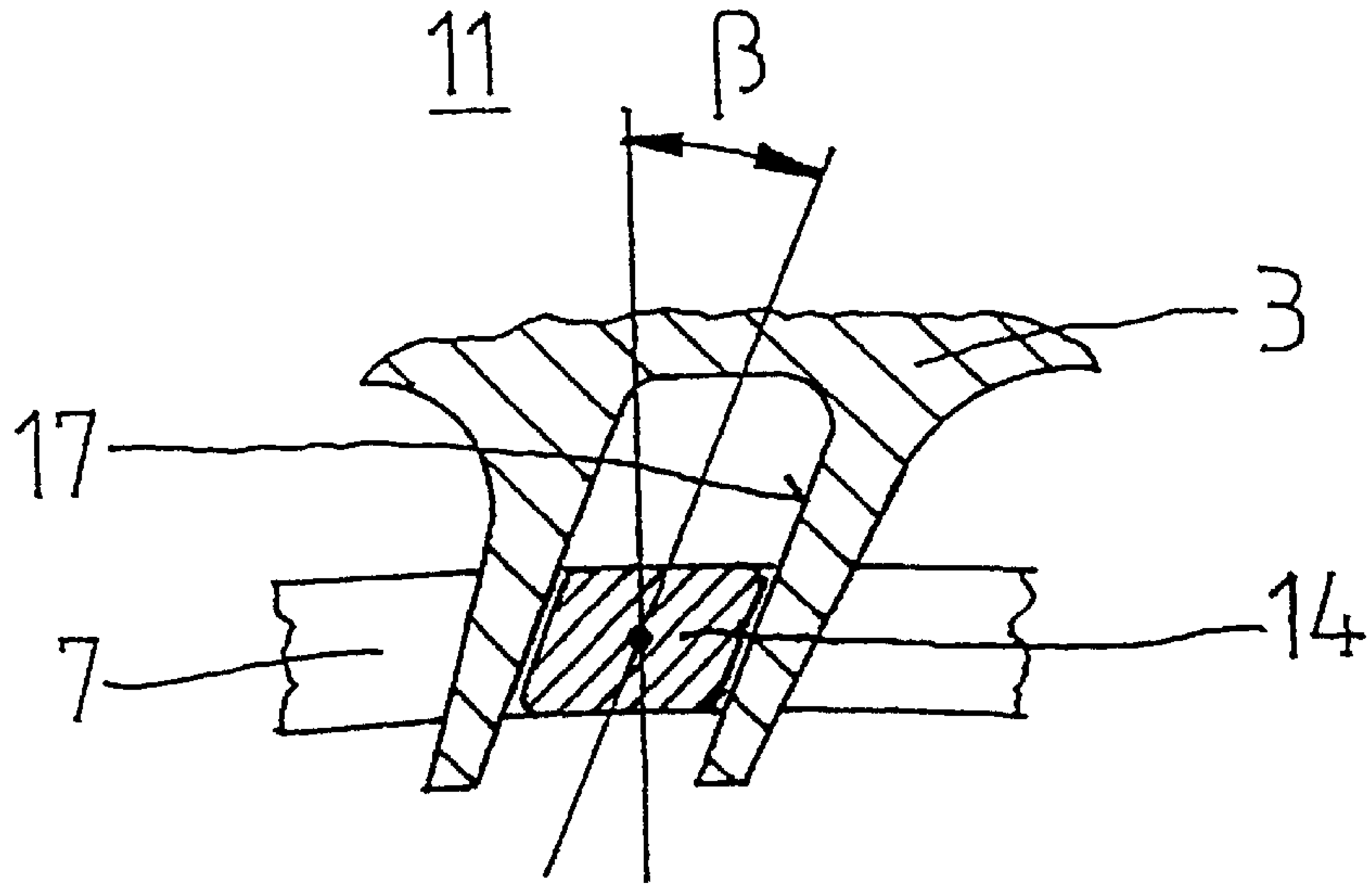


Fig. 3

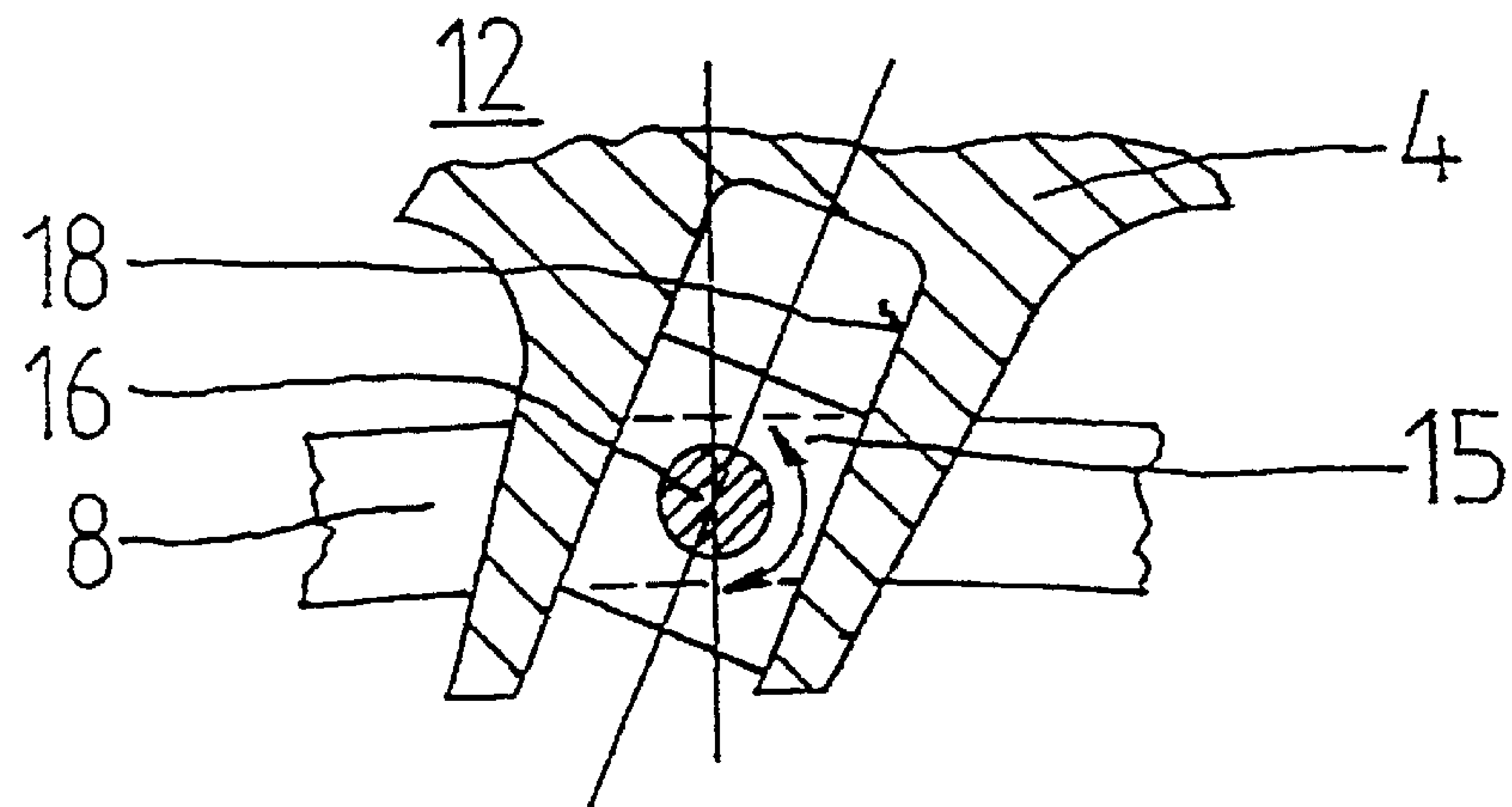


Fig. 4

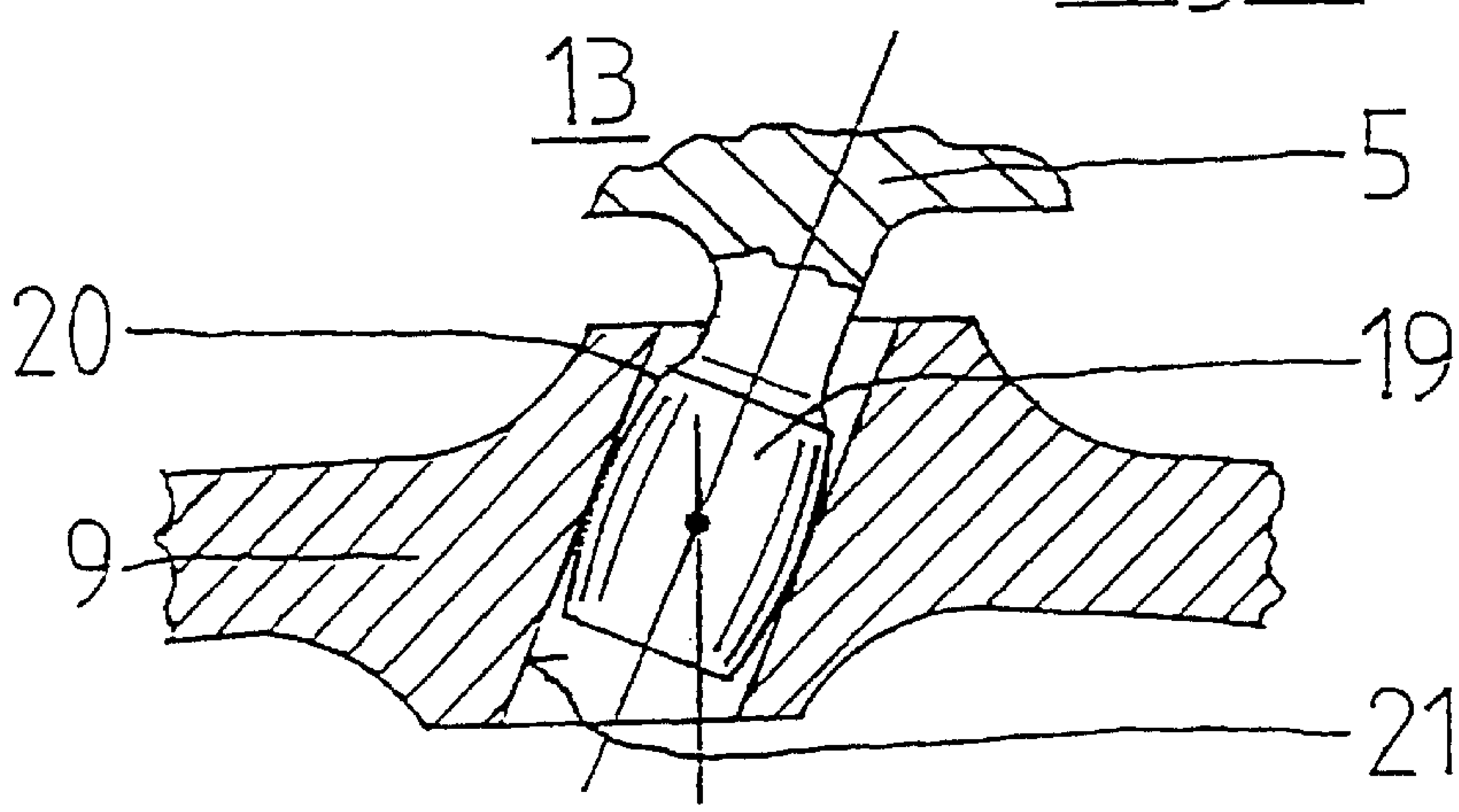


Fig. 5

SUSPENSION

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates to the suspension of an annular secondary structure on a primary structure, in particular of a stator structure acted upon by hot gas on a casing structure of a gas turbine, in the form of what may be referred to as a spoke-type centering device.

Spoke-type centering devices are used in order to suspend annular secondary structures centrically on mostly likewise annular or tubular primary structures. In this case, radial relative movements of the structures in relation to one another are to be possible essentially without constraining forces and deformations, while at the same time concentricity is maintained. The principle is appropriate, in particular, when widely differing thermal expansions of two concentric structures are to be compensated. If the secondary structure is relatively elastic, that is to say has low dimensional stability, it should be, as far as possible, stabilized and stiffened via the suspension.

German patent publication DE 198 07 247 C2 discloses a turbomachine with rotor and stator, which has at least one specially designed guide-vane ring. The latter is designed as a self-supporting component with a reinforcement on the inner shroud and with a segmented outer shroud. The guide-vane ring is positioned in the casing of the turbomachine via a spoke-type centering device having at least three "spokes". The sliding guides of the spoke-type centering device have bearing journals in bearing bushes, and the linear direction of movement in each sliding guide runs radially with respect to the guide-vane ring and casing.

It is likewise customary to implement the sliding guides by way of sliding blocks running in straight grooves, the direction of movement running, as is usual, radially with respect to the coupled structures. Experience shows that pronounced wear often occurs on the sliding elements of conventional spoke-type centering devices. Permanent deformations of the thin-walled secondary structures have sometimes been detected. Both types of damage indicate that higher forces than should occur under ideally rotationally symmetrical conditions obviously arise in the guides. The cause is probably non-rotationally symmetrical expansion states of the structures, which, in gas turbines, may be brought about, in particular, by non-homogeneous gas temperature distributions. Especially where structures of large diameter are concerned, with a multiplicity of sliding guides, that is to say of "spokes", the risk of the occurrence of high constraining forces increases. By virtue of geometry, the orientation of the direction of movement changes only slightly from guide to guide, so that, in the event of expansion of the secondary-structure region located between them, jamming may occur in both guides because of a fall below the angle of friction, with the result that free structure expansion becomes impossible. A further disadvantage of the conventional radial spoke-type centering devices is that these "soft" secondary structures are stiffened only when there is an odd number of sliding guides ("spokes").

In view of these disadvantages of known spoke-type centering devices, one object of this invention is to find a suspension for an annular secondary structure on a primary structure in the manner of a spoke-type centering device having at least three differently oriented sliding guides. The suspension prevents or largely reduces the constraining forces and deformations, and also wear, and makes it possible to stiffen flexible secondary structures, irrespective of whether there is an even or odd number of sliding guides.

According to the invention, the linear direction of movement of each sliding guide is inclined at an angle β to the radial direction of the structures, so that the relative movement acquires a radial component and a tangential component. Guide jamming, with all its disadvantages, is thereby avoided with a high degree of reliability. This applies to homogeneous and non-homogeneous dimensional changes of the secondary structure. In the case of homogeneous rotationally symmetrical expansion or contraction of the secondary structure, the latter also executes a small relative rotation in relation to the primary structure for kinematic reasons, which in most cases is acceptable. In the case of non-homogeneous locally differing expansion or contraction of the secondary structure, the latter is deformed elastically to some extent away from the annular configuration. However, the sliding-guide forces resulting from this are substantially lower than during the jamming of a conventional radial spoke-type centering device. The dimensional deviations are likewise kept within acceptable limits. One effect of the invention, namely to increase dimensional stability, may permit the secondary structure to be designed to be more elastic and lighter than in a conventional spoke-type centering device.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in more detail below with reference to the figures.

FIG. **1** shows a cross section through a suspension with eight sliding guides, reproducing two different rotationally symmetrical expansion states of a secondary structure,

FIG. **2** shows a part cross section through the suspension according to FIG. **1** with an asymmetric expansion state of the secondary structure,

FIG. **3** shows a sliding guide with a rigid sliding block and slot,

FIG. **4** shows a sliding guide with a pivotable sliding block and a slot, and

FIG. **5** shows a sliding guide with a pin and a bush.

DETAILED DESCRIPTION OF THE INVENTION

The illustrations according to FIGS. **1** and **2** are as far as possible in diagrammatic form, in order to reproduce the invention as simply and clearly as possible. The suspension **1**, in the form of what may be referred to as a spoke-type centering device, comprises eight sliding guides **10** which are distributed uniformly on the circumference. The angular interval of the guides thus amounts to 45°. The structures, primary structure **2** and secondary structure **6**, which are coupled by means of the suspension **1**, are indicated in actual fact only as hatched fragments in the upper region of FIG. **1**. Instead of the real annular secondary structure **6**, a closed polygon with rigid chords **S1** to **S8** and with joints between the chords in the sliding guides **10** is considered here. The eight radial straight lines emanating from the structure center and in each case offset at 45° indicate only the structure-related radial direction R to the or in the chord joints and are not to be understood as structural elements. The sliding guide **10** on the angle bisecting line (45°) of the right upper quadrant shows that the linear direction of movement L of the sliding guide **10** deviates by an angle β from the radial direction R and therefore, de facto, has a radial and a tangential movement component. The selected angle β is preferably larger than the maximum angle of friction α to be expected in the sliding guide **10**, so that, with a high degree of reliability, there need be no fear of jamming of the sliding-guide pairing. In the present conceptually simplified suspension **1** which has an articulated chord polygon and the sliding guides **10** of which are inclined clockwise at an angle β to the radial direction R, the change in length (expansion, contraction) of a chord leads to a sliding movement in the sliding guide at the chord end located clockwise at the front, since, on each chord, in each case only one sliding guide is inclined to the transverse direction of the chord by markedly more than the angle of friction, whereas the other sliding guide is approximately transverse to the chord.

To understand these kinematics more clearly, the sliding guide **10** at the top right in FIG. **1** is given additional particulars. In addition to the structure-related radial direction R at the location of the sliding guide, to the linear direction of movement L of the sliding guide **10** and to the angle β between R and L, there can also be seen, represented by dashes and dots, the straight prolongation V of the chord **S8**, the transverse direction T, at an angle of 90° to the chord **S8**, and the angle βeff between L and T. Furthermore, dots indicate what may be referred to as the friction cone of the sliding guide **10**, the apex angle of which is twice as large as the angle of friction α. Since, here, the direction of movement L runs perpendicularly to the adjacent chord **S7**, the friction cone is mirror-symmetrical with respect to **S7**. Since the prolongation V lies well outside the friction cone, a change in length of **S8** leads to a defined jam-free movement of the "joint" between **S8** and **S7** in the L-direction. It would therefore be sufficient, in theory, for the selected angle βeff to be larger than α. Since a real homogeneous secondary structure behaves differently from the simple articulated chord polygon, for safety reasons even the angle β should be larger than α.

For clearer understanding, terms, such as coefficient of friction and angle of friction, will be dealt with briefly at this juncture. The relation between the coefficient of friction f and the angle of friction α is as follows:

$$f = \tan \alpha$$

Hence, α is the inverse function of the tangent of f:

$$\alpha = \text{inv} \tan f$$

The following values for f may be gathered from technical encyclopaedias:

Solid-state friction f

Metal/metal 0.3÷1.5

Ceramic/ceramic 0.2÷1.5

Plastic/metal 0.2÷1.5

Boundary friction 0.1÷0.2

Mixed friction 0.01÷0.1

Fluid friction ≈0.01

At predetermined actual coefficients of friction, the following angles of friction are obtained:

f	α
0.2	11.3°
0.3	16.7°
0.5	26.6°

-continued

f	α
1.0	45.0°

As regards the suspension **1** illustrated, with 8 "spokes", the angle β, amounts to 22.5°. This inclination would probably be sufficient for a maximum coefficient of friction f<0.4. In the case of higher friction, the inclination β to the radial would have to be increased correspondingly.

FIG. **1** illustrates the chords **S1** to **S8**, twice in each case to be precise, as unbroken and as broken straight lines. The unbroken chord polygon stands for a "cold" contracted state of the secondary structure **6**. The broken larger chord polygon stands for a "hot" uniformly expanded state of the secondary structure **6**. The primary structure **2** is in this case to remain unchanged geometrically for the sake of simplicity, so that that part of the sliding guides **10** which belongs to the primary structure does not move. In the event of an identical expansion or contraction of all the chords, the angles of articulation of the chord polygon obviously remain unchanged. This means, in terms of the real secondary structure **6**, that its diameter changes, but not its shape (annulus). The concentric position in relation to the primary structure **2** also remains. It can also be seen that, at a transition from the unbroken position to the broken position, the chord polygon, and consequently the secondary structure, executes a small rotational movement clockwise through an angle γ, specifically as a result of the angle β of the sliding guides **10**. In practical applications, this slight rotation due to the invention is, as a rule, of no importance for the functioning of the structure.

In contrast to FIG. **1**, FIG. **2** shows an asymmetric expansion of the chord polygon. When turbomachines are used in practice, operating states with a highly asymmetric temperature distribution over the flow cross section may occur. Thus, according to FIG. **2**, essentially only the chord **S1** is to undergo thermal expansion. In this case, the sliding guide **10** at the "joint" between **S1** and **S8** executes a yielding movement obliquely upwards and to the right at the angle β. The chord **S8** is in this case co-pivoted about its right-hand "joint" in relation to the chord **S7**, but in practice does not change its length. As a consequence of the kinematics predetermined by the sliding guides **10**, a movement in the sliding guide **10** between **S1** and **S8** upwards and to the right, with the chord length of **S8** remaining the same, results in only a negligible movement in the sliding guide between **S8** and **S7** downwards to the left, which practically cannot be illustrated in FIG. **2**. Thus, de facto, the chord **S8** executes only a pivoting movement about its "joint" in relation to **S7**, and the chord **S7** remains in its position, as does the chord **S2**. It can be seen, however, that the "angles of articulation" between the chords **S2**/**S1**, **S1**/**S8** and **S8**/**S7** change. This means, in terms of the real secondary structure **6**, that it is deformed asymmetrically and is no longer exactly circular. In this case, however, the actual changes in dimension and in shape are, as a rule, so small that their effects on functioning and on mechanical load can be ignored. The constraining forces and deformations occurring without the present invention would, as a rule, be more harmful.

FIGS. **3** to **5** show actual exemplary embodiments of sliding guides **11** to **13** with an inclination β according to the invention.

FIG. **3** shows a sliding guide **11** with a sliding block **14** in a slot **17**. The slot **17** is integrated into the primary structure **3**, and the sliding block **14** is connected firmly to the secondary structure **7** or is worked out from the latter. The sliding block **14** is deliberately illustrated with rounded corners and with sliding-surface clearance in the slot **17**. During operation, for example in the event of asymmetric structure deformation, slight tilting movements to the sliding block **14** in the slot **17** may occur, clearance and corner rounding being intended to prevent excessive friction, wear and jamming.

FIG. **4** likewise shows a sliding guide **12** with a slot **18** integrated into the primary structure **4** and with a sliding block **15**, although, in contrast to FIG. **3**, the latter is pivotable about a shaft **16** which is connected firmly to the secondary structure **8**. Small relative rotations of the structures **4**, **8** are thereby easily possible. The fit of the sliding block **15** in the slot **18** can be made precise and largely free of play.

Finally, FIG. **5** shows a sliding guide **13** with a pin **19** in a bush **21**. The pin **19**, here, is connected firmly to the primary structure **5**, and the circular-cylindrical bush **21** is integrated into a thickening of the secondary structure **9**. The outer surface **20** of the pin **19** has a convex and rotationally symmetrical shape, in order to avoid edge stress or jamming during structure rotation. The convex shape may correspond, in an extreme case, to a spherical shape.

What is claimed is:

1. A suspension of an annular secondary structure on a primary structure, the suspension being of a stator structure acted upon by hot gas on a casing structure of a gas turbine, in the form of a spoke-type centring device comprising at least three sliding guides which are distributed over a structure circumference at equal angular intervals, each of the guides allowing at least a linear relative movement between the primary and the secondary structures transversely to their axial direction, a linear direction of movement changing from one sliding guide to the next by an angle which corresponds to an angular interval of the sliding guides, wherein the linear direction of movement of each sliding guide in relation to a structure-related radial direction at the location of the sliding guide runs at an angle having a radial direction component and a tangential direction component.

2. The suspension according to claim **1**, wherein the angle is defined as a function of a maximum angle of friction to be expected in each sliding guide.

3. The suspension according to claim **2**, wherein each sliding guide comprises a sliding block and a slot or a pin and a bush, wherein each sliding block or pin is connected to one of the structures, and wherein each slot or bush is connected to the other of the structures.

4. The suspension according to claim **3**, wherein at least one of the sliding block and the slot, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

5. The suspension according to claim **3**, wherein at least one of the pin and the bush, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

6. The suspension according to claim **3**, wherein the sliding block of each sliding guide has convexly curved sliding surfaces, or wherein the pin of each sliding guide has a convex outer surface.

7. The suspension according to claim **6**, wherein at least one of the sliding block and the slot, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

8. The suspension according to claim **6**, wherein at least one of the pin and the bush, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

9. The suspension according to claim **3**, wherein the sliding block of each sliding guide is arranged pivotably about a shaft oriented in the axial direction of the primary and secondary structures.

10. The suspension according to claim **9**, wherein at least one of the sliding block and the slot, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

11. The suspension according to claim **9**, wherein at least one of the pin and the bush, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

12. The suspension according to claim **1**, wherein each sliding guide comprises a sliding block and a slot or a pin and a bush, wherein each sliding block or pin is connected to one of the structures, and wherein each slot or bush is connected to the other of the structures.

13. The suspension according to claim **3**, wherein at least one of the sliding block and the slot, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

14. The suspension according to claim **12**, wherein at least one of the pin and the bush, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

15. The suspension according to claim **12**, wherein the sliding block of each sliding guide has convexly curved sliding surfaces, or wherein the pin of each sliding guide has a convex outer surface.

16. The suspension according to claim **15**, wherein at least one of the sliding block and the slot, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

17. The suspension according to claim **15**, wherein at least one of the pin and the bush, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

18. The suspension according to claim **12**, wherein the sliding block of each sliding guide is arranged pivotably about a shaft oriented in the axial direction of the primary and secondary structures.

19. The suspension according to claim **18**, wherein at least one of the sliding block and the slot, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

20. The suspension according to claim **18**, wherein at least one of the pin and the bush, sliding on each other, has a wear-resistant metallic and/or ceramic sliding-surface coating.

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